ABSTRACT

Local site conditions are known to influence ground motion during earthquake events and increase the severity of damage. Data from earthquakes are useful to study the response but they are available only from active regions. Ubiquitous ambient vibrations on the other hand offer a more practical approach to quantify site responses. This thesis explores the use of various methods for obtaining site responses. The primary area of study is the Kachchh rift basin, NW India, a Mesozoic rift that features significant lateral variations in surface geology and has experienced ground responses during 1819 and 2001 earthquakes. The Mw 7.6, 2001 event was followed by hundreds of aftershocks, which were recorded by temporary networks. In this study we have used earthquake signals as well as ambient vibrations to understand site response in various parts of the basin. In addition we have collected data from a few sites from the Indo-Gangetic plains and Kathmandu valley, both affected by large earthquakes, 1934 the M ~ 8 (Bihar) and 2015, Mw 7.8 (Nepal). Velocity and acceleration records from a network of eight stations in the Kachchh Rift were used to evaluate site responses using Standard Spectral Ratio (SSR) and Horizontal to Vertical spectral ratio (HVSR-E) methods. Ambient vibrations were analyzed following Nakamura's H/V method (HVSR-AV), for data collected from 110 sites that represent different field conditions within the Kachchh Rift. Fundamental resonance frequency (f0) varied between 0.12 – 2.30 Hz, while the amplification factor (A0) was in the range of 2.0 – 9.1. We found that higher A0 and liquefaction index (Kg) values were mostly associated with higher liquefaction potential. Using a close network of stations, we studied the role of site response in damage to the Bhuj city that suffered maximum damage in 2001; our results suggest that site response was not a significant factor.

Studies based on passive data were complemented by Multi-channel Analysis of Surface Waves (MASW) to map shear wave velocities of the various subsurface units up to depths of 10m (Vs10) and 30m (Vs30). Our results imply average Vs could be a good proxy to characterize site amplifications where sediment thicknesses are shallow. Power law relationship between f0 and thickness (h) suggest a strong positive correlation (r = 0.89) adding credence to HVSR-AV method, making it a cost-effective alternative to MASW to infer site conditions. Further, to understand the influence of topography on site effects, we analyzed data from hills, valleys and their edges, both from the Kachchh rift and Kathmandu valley. Sites on the edges of valleys showed multiple, fuzzy peaks in the low frequency range (< 1 Hz) and broad peaks attributable to sites prone to higher damage. Spectrograms generated through Huang-Hilbert Transforms (HHT) suggested focusing of energy in narrow frequency bands on the edges, while valleys tend to scatter energy over wide frequencies. Although our current results are based on limited observations, we recognize spectral analysis as a powerful tool to quantify site effects in regions with significant topography.

It is known that coseismic liquefaction could lead to nonlinear behavior wherein the near-surface soil layer loses its shear strength, causing a reduction of its fundamental resonance frequency. We used data from selected sites of coseismic liquefaction to highlight the significance of nonlinear effects in site response. Earthquake signals and ambient vibrations from Umedpur, a region that experienced intense liquefaction during 2001 were used in this analysis. Here we followed an empirical decomposition method based on HHT and signals were decomposed as many intrinsic mode functions (IMFs) that showed characteristic peaks for events of various values of PGAs. Thus, the first IMF for events with relatively higher PGAs (0.03g) showed distinct peaks for the S wave coda part, which were not noted for those with lower PGA (0.01g). These observations in a region of coseismic liquefaction are useful in developing models for quantifying nonlinear behavior.

In conclusion, site response studies using different types of data and processing techniques in regions affected by recent earthquakes brings out the scope and limitations of each of these sets of data and techniques. This study suggests that ambient vibrations provide reasonable estimates of site response and can be reliably used in regions where earthquake data are not available.